

EVALUATION OF UPGRADED MISR STEREO MOTION VECTORS

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Abstract

At the 10th International Winds Workshop Lonitz and Horváth (2011) presented a detailed comparison of MISR stereo motion vectors (SMVs) and Meteosat-9 cloud motion vectors (CMVs). Since then, the MISR wind retrieval algorithm has undergone the following major upgrades. (i) A more accurate area matcher has replaced the noisy Nested Max feature matcher. (ii) The resolution of SMVs has been increased from 70.4 km to 17.6 km. (iii) The quality control scheme of SMVs has been made more compatible with that of CMVs. (iv) Sub-pixel georectification corrections have been introduced at Level 2 processing to reduce the cross-swath dependence of SMVs.

This study has investigated the effects of the above stereo upgrades on the SMV-CMV comparison. In general, the comparison of the E-W wind components has remained practically unchanged, that of the N-S wind components, however, has improved significantly over the entire Meteosat-9 disk and at all vertical levels. MISR SMVs have become 1-2 m s⁻¹ more southerly (or less northerly), which in turn has reduced SMV heights by 100-200 m, halving the mean MISR – Meteosat-9 height difference. The coverage of high-quality SMVs has also greatly increased, especially at mid- and high-levels, and the cross-swath SMV bias has been reduced by a factor of three.

DATA AND METHODOLOGY

The data set of Lonitz and Horváth (2011) comprised ~225,000 collocated high-quality SMV-CMV pairs. To allow a direct comparison with our previous results, we have simply replaced the 70.4-km (low-res) SMVs with 17.6-km (high-res) SMVs but retained the original Meteosat-9 CMVs. As an example, Figure 1 shows low-res and high-res MISR winds for an extratropical cyclone in the southern oceans. A low-res SMV has been replaced with its nearest-neighbor hi-res SMV when analyzing quality indices and with the average of all hi-res winds in its respective 70.4-km domain for every other calculation in order to be consistent with the 72-km nominal resolution of Meteosat-9 CMVs.

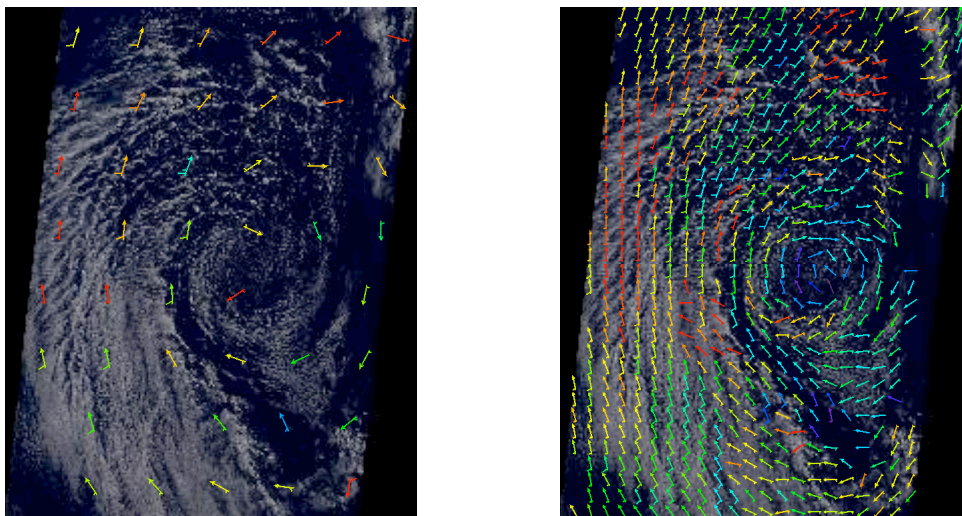


Figure 1: Low-res 70.4-km (left) and hi-res 17.6-km (right) MISR SMVs for path 191, orbit 45232, blocks 115-118. Colors varying from magenta to red correspond to heights increasing from 0.5 km to 2.5 km.

DEPENDENCE ON QUALITY INDICATORS

Figure 2 shows the SMV-CMV N-S wind rmsd as a function of MISR and Meteosat-9 quality indices (QI), separately for low-res and high-res MISR SMVs. The low-res MISR QI varied from 0 to 4 with QI=3 and QI=4 corresponding to ‘good’ and ‘very good’ retrievals, respectively. Similar to the Meteosat-9 quality control scheme, the new hi-res MISR QI varies from 0 to 1. For consistency, however, here we have binned hi-res SMVs according to the QI of the low-res winds they replaced.

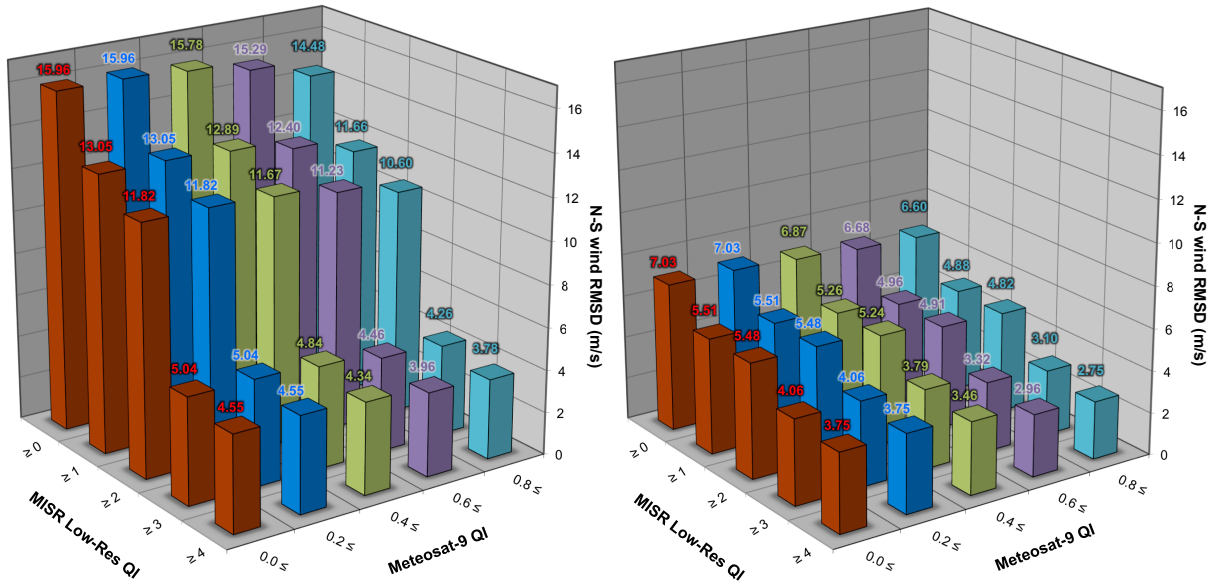


Figure 2: Dependence of SMV-CMV N-S wind rmsd on quality indicators for low-res (left) and hi-res (right) MISR winds.

The N-S wind rmsd has dropped significantly and now varies smoothly with MISR QI for hi-res SMVs. The largest improvements in rmsd and, thus, retrieval quality, have occurred for originally low-quality MISR winds ($QI \leq 2$), while the quality gain was more modest ($\sim 1 \text{ m s}^{-1}$) for ‘good’ and ‘very good’ low-res SMVs. The increase in coverage of high-quality MISR winds is analyzed further in Figure 3 as a function of altitude.

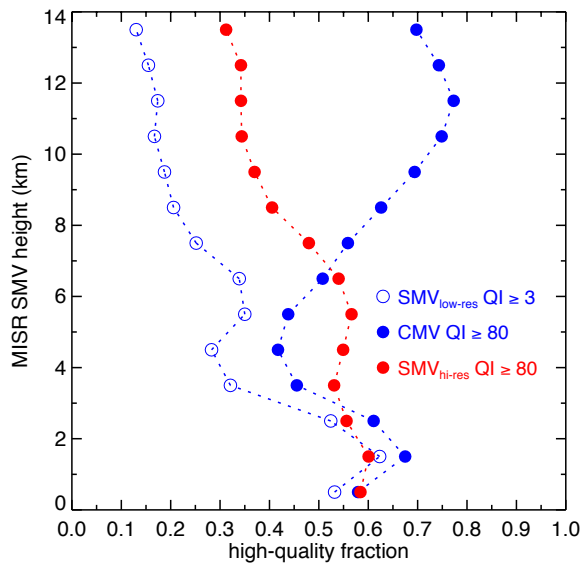


Figure 3: Fraction of high-quality retrievals vs. height for low-res and hi-res MISR SMVs and Meteosat-9 CMVs.

For hi-res SMVs we have used the same quality threshold as recommended for CMVs ($QI \geq 80$), although this value might have to be refined once the mapping between the hi-res MISR and Meteosat-9 QI schemes is better understood. As shown, the quality of low-res and high-res SMVs is comparable and similar to that of CMVs for low-level clouds. At levels above 3 km, however, the coverage of high-quality MISR retrievals doubles in the upgraded stereo algorithm and for mid-level clouds it is even better than that of CMVs –for high-level clouds CMVs remain the retrievals that are most often of good quality.

FULL-DISK ANNUAL-MEAN DIFFERENCE STATISTICS

Table 1 summarizes the annual-mean SMV-CMV difference statistics, separately for low-res and hi-res MISR winds. There has practically been no change in the E-W wind comparison. However, the new stereo algorithm has eliminated the $\sim 1 \text{ m s}^{-1}$ MISR N-S wind bias and has reduced the N-S wind rmsd to a level comparable with the E-W wind rmsd ($\sim 3 \text{ m s}^{-1}$). The mean height difference has also been reduced by half due mainly to a $\sim 200 \text{ m}$ decrease in the height of low-level SMVs, which dominate the MISR data set.

| | E-W bias | E-W rmsd | E-W corr. | N-S bias | N-S rmsd | N-S corr. | Height bias |
|-------------|--------------------------|-------------------------|-----------|--------------------------|-------------------------|-----------|-------------|
| low-res SMV | -0.42 m s^{-1} | 2.50 m s^{-1} | 0.97 | -1.12 m s^{-1} | 4.23 m s^{-1} | 0.84 | 443 m |
| hi-res SMV | -0.34 m s^{-1} | 2.77 m s^{-1} | 0.96 | -0.03 m s^{-1} | 3.09 m s^{-1} | 0.89 | 188 m |

Table 1: SMV-CMV comparison statistics, separately for low-res and hi-res MISR retrievals.

REGIONAL IMPROVEMENTS IN N-S WIND COMPARISON

The new stereo algorithm has improved the SMV-CMV comparison not only in a global mean sense but regionally as well. As shown in Figure 4, the N-S wind rmsd has decreased by $1\text{-}2 \text{ m s}^{-1}$ and correlation has increased by $10\text{-}20\%$ practically over the entire Meteosat-9 disk. The increase in correlation was particularly pronounced in the tropics and sub-tropics, with perhaps the exception of the marine Sc region off Namibia where agreement was already very good with the low-res algorithm.

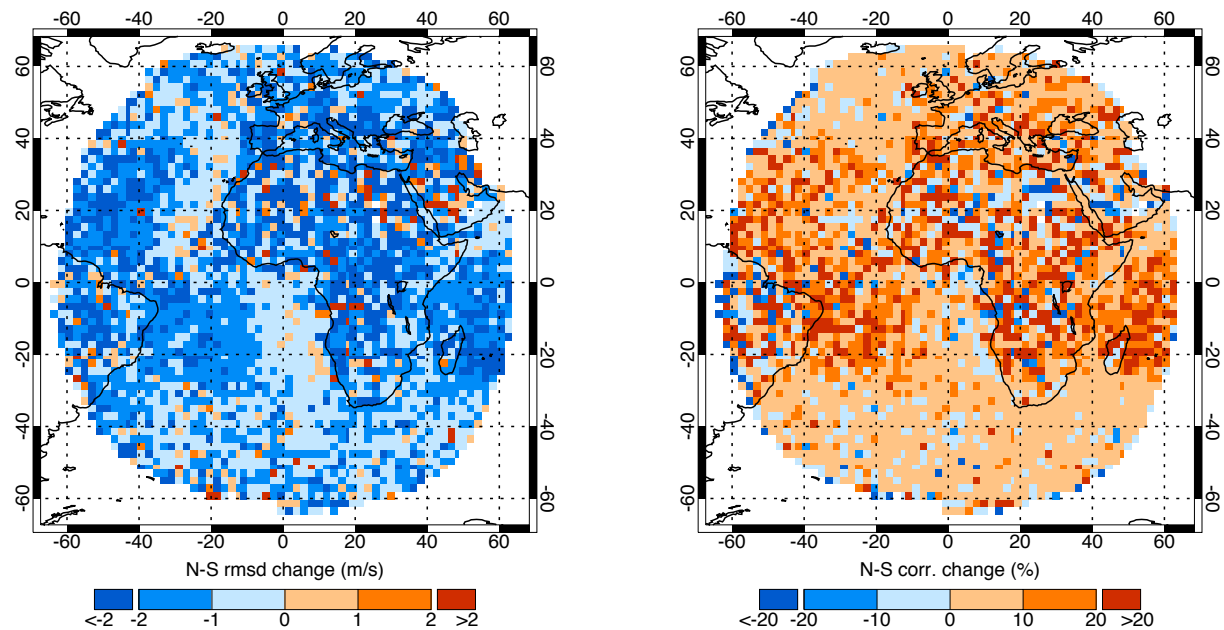


Figure 4: Change in SMV-CMV N-S wind rmsd (left) and correlation (right) between hi-res and low-res MISR retrievals over the Meteosat-9 disk.

IMPROVEMENTS IN ZONAL-MEAN STATISTICS

Zonal-mean SMV-CMV comparison statistics for mid-level (3-7 km) clouds are plotted in Figure 5 for low-res and hi-res MISR winds. There has been a dramatic decrease in N-S wind mean difference and rmsd at all latitudes with the new stereo algorithm, resulting in values comparable to E-W wind differences. As discussed previously, the N-S wind correlation has also shown a very pronounced increase in the tropics and sub-tropics. The E-W wind statistics have not changed significantly, except in the latitude band 15°S-35°S where rmsd increased and correlation decreased noticeably for hi-res winds; a full explanation of the latter will require further analysis. Similar but slightly smaller improvements in zonal-mean statistics have been noticed for low- and high-level clouds as well.

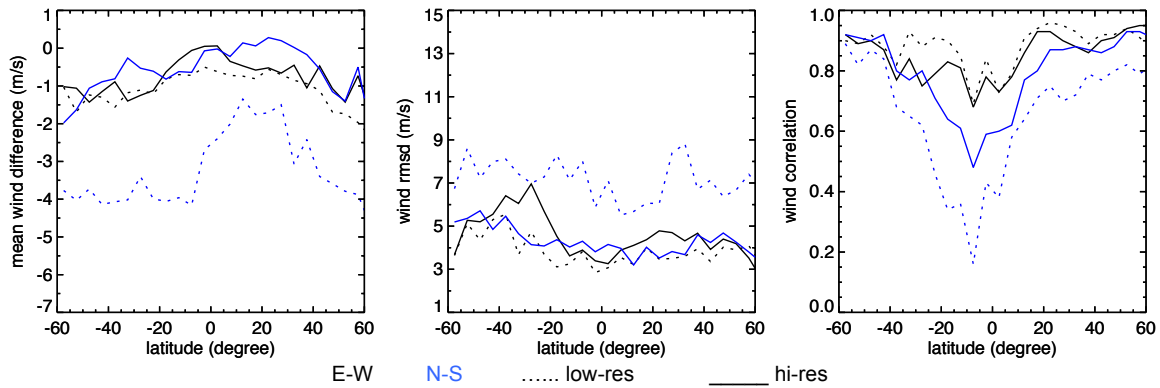


Figure 5: Meridional variation of mid-level SMV-CMV comparison, separately for low-res and high-res MISR winds.

REDUCTION OF MISR CROSS-SWATH BIAS

Lonitz and Horváth (2011) documented a cross-swath bias in MISR E-W wind, N-S wind, and height of 0.6 m s^{-1} , 2.6 m s^{-1} , and 210 m, respectively. This artifact was traced back to sub-pixel co-registration errors in the B and D cameras stemming from a simplified treatment of focal plane distortions in the MISR Camera Geometric Model. The updated stereo algorithm has introduced georectification corrections at Level 2 processing to mitigate this problem. As Figure 6 clearly demonstrates, these corrections have almost completely eliminated the cross-swath bias in the E-W wind component and, more importantly, have reduced it to within $\pm 0.5 \text{ m s}^{-1}$ in the N-S wind component, with a corresponding reduction in the height bias. Further statistical improvements can be obtained if cross-swath bias estimates derived from cloud-free ground retrievals are subtracted from the MISR SMVs.

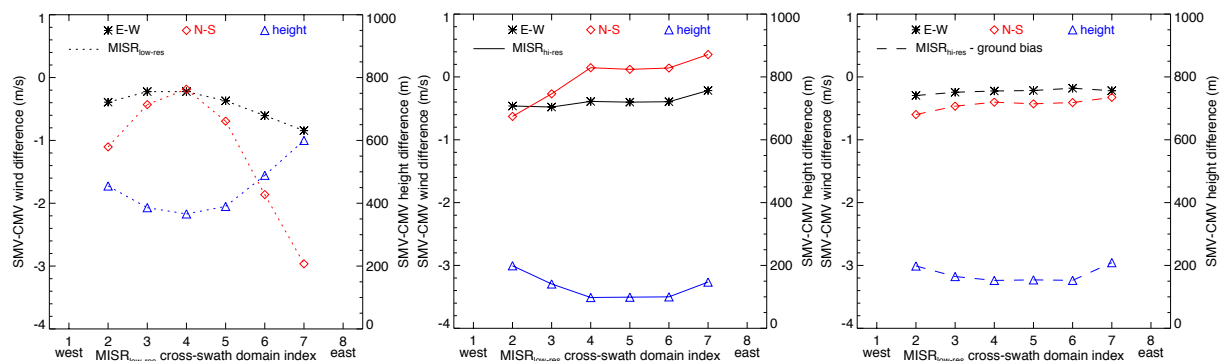


Figure 6: Cross-swath dependence of SMV-CMV wind and height difference for low-res (left) and high-res (middle) SMVs. The right panel plots results obtained with additional corrections derived from ground retrievals.

VERTICAL VARIATIONS IN COMPARISON STATISTICS

The MISR algorithm upgrades have yielded significant improvements in SMV-CMV comparison statistics throughout the entire atmosphere. Figure 7 shows impressive increases in N-S wind correlations, especially at mid- and high-levels. These have been accompanied by only slight decreases in E-W wind correlations, which, nevertheless, will require further analysis.

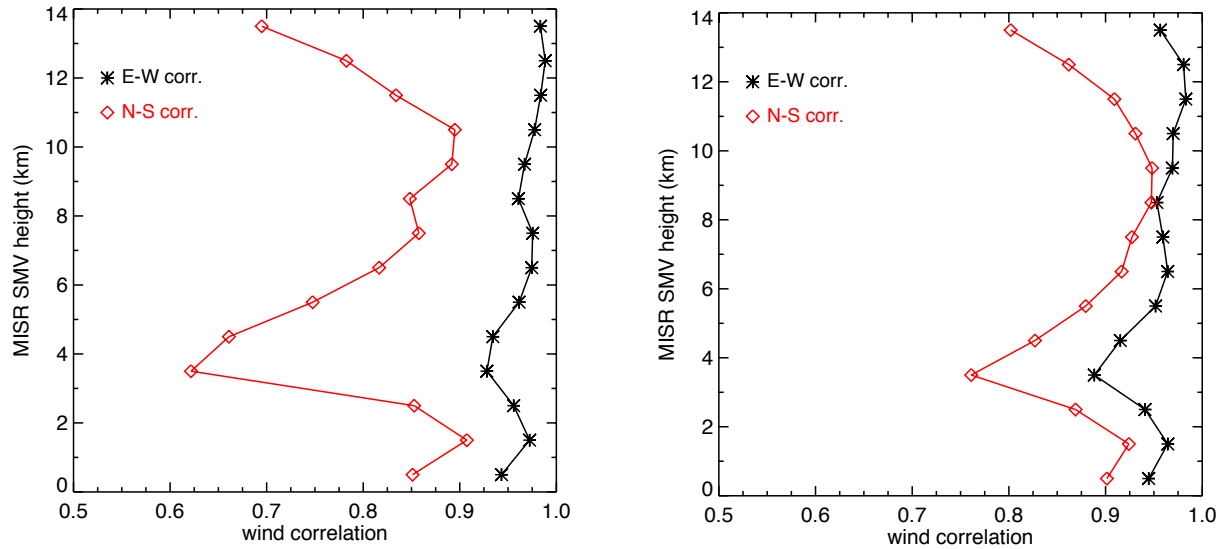


Figure 7: SMV-CMV wind correlation profiles for low-res (left) and high-res (right) MISR retrievals.

For low-res SMVs, the N-S mean wind difference and rmsd showed a large and systematic increase with height, while values for the E-W wind component were generally smaller and only slowly varying with altitude. With hi-res SMVs, the deterioration in N-S wind difference statistics has been almost completely eliminated; the E-W wind comparison is slightly better only for the highest clouds above 8 km. For both wind components the SMV-CMV mean difference and rmsd are now within $\pm 2 \text{ m s}^{-1}$ and $3\text{-}6 \text{ m s}^{-1}$, respectively, at all elevations.

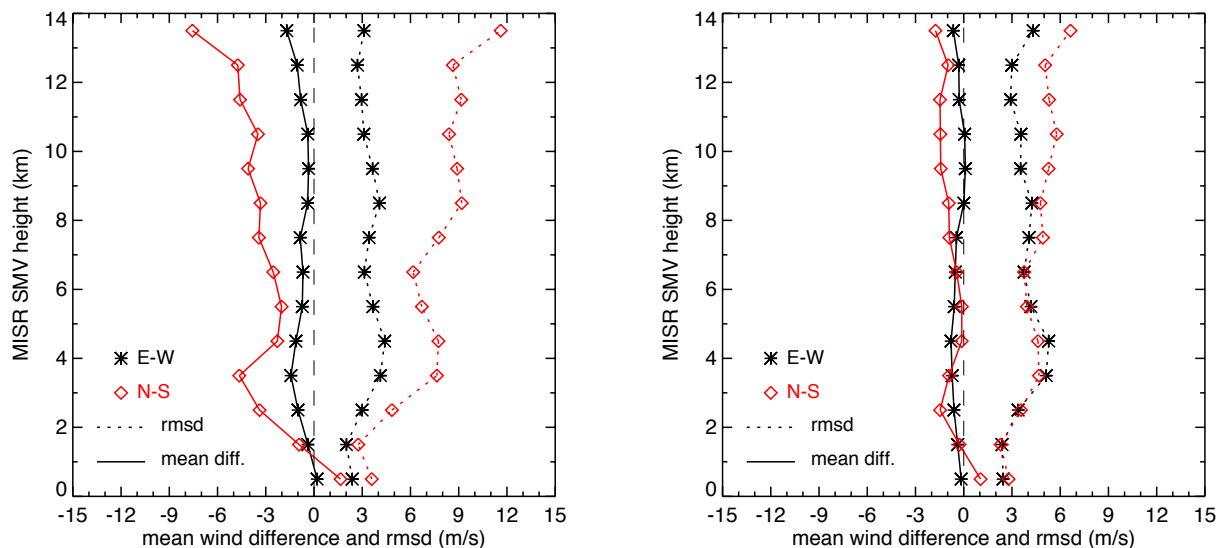


Figure 8: SMV-CMV mean wind difference and rmsd profiles for low-res (left) and high-res (right) MISR retrievals.

SUMMARY

The upgrades implemented in the stereo algorithm since the last workshop have significantly improved the agreement of MISR winds to Meteosat-9 winds, without introducing any apparent negative side effects. Compared to the 70.4-km SMVs, the new 17.6-km SMVs have double coverage at mid- and high-levels, much reduced cross-swath bias, and a slower decrease in quality with height. In addition, the accuracy of the N-S wind components is now broadly comparable with that of the E-W components. Experience also indicates that successful SMV retrievals are achievable at resolutions even better than 17.6 km. Such high-resolution stereo winds might be useful in fine-scale cloud process studies.

REFERENCES

Lonitz, K., and Á. Horváth (2011) Comparison of MISR and Meteosat-9 cloud-motion vectors. *Journal of Geophysical Research - Atmospheres*, **116**, D24202, doi:10.1029/2011JD016047.